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XIII - SunCatcher's unique patented profile - "The Magic Sauce"

The shape of the SunCatcher PSG, in particular viewed from the East or West side, is critical to the performance of the greenhouse. The general shape of the SunCatcher is similar to a non-focusing concentrating collector consisting of a south-facing reflective flat plate with mirrors attached to its north and south edges. When the mirrors are set at the correct angle, they reflect solar radiation onto the absorber plate.[1]

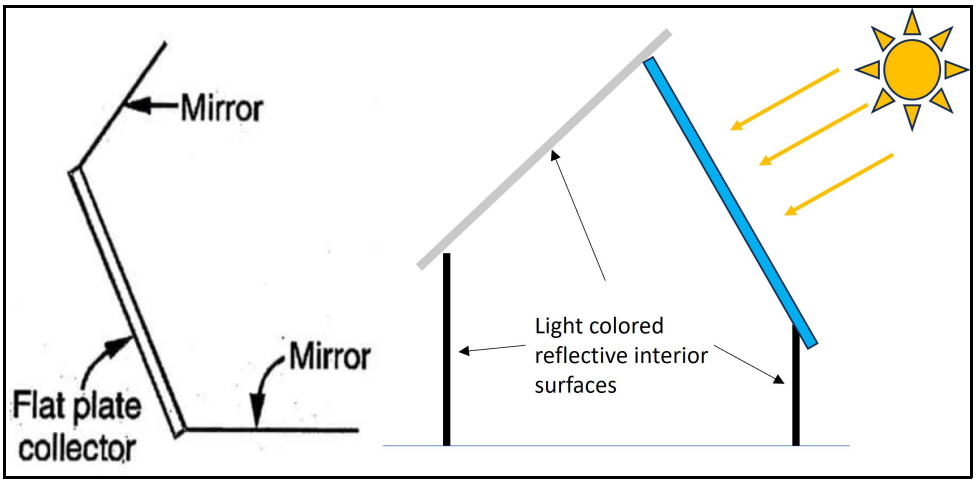


Figure XIII.1. Instead of a plate collector, the SunCatcher uses thermal mass, no bottom mirror, with the top mirror being the glossy white ceiling.

From our research on the Parkway SunCathcer, we learned that the 90^0 angle of the glazing to the roof (i.e., roof at a 30^0 angle from horizontal) worked well for the 12 ft width of these structures. We wondered if that same profile could be up-scaled into larger structures that would interest commercial growers. We learned from the 24x12 ft Laurel Ridge SunCatcher that, yes, we could make them longer, but not necessarily increase their width without the structure getting too dark in the back third along the north wall for successful plant growing. The lack of sufficient sunlight was one issue we struggled with in the modified gothic greenhouse in Valle Crucis (at 24 ft width by 21 ft length, the north half hoop roof insulated with Reflectix). But, it would be similar in PSGs with the 60^0 glazing angle optimized for winter solstice sun. With the sun being about 30^0 above the horizon around the Winter Solstice, the light enters the structure parallel to the ceiling – good to warm up the thermal mass but no light would be reflected off the ceiling that could provide a light boost to the plants and thermal mass. And, as the sun starts getting higher in the sky as we approach Spring (or, vice-versa, as Fall progresses), little to any light will reflect off the ceiling limiting light for plants growing further toward the North wall. So, in later designs, we increased the angle of the roof from 30 to 45^0 which allowed for greater widths and a larger glazing area to improve winter light distribution for more even growing conditions throughout the interior (Figure XIII.2).

[1]Source: https://www.engineeringa2z.com/solar-collectors-types-advantages

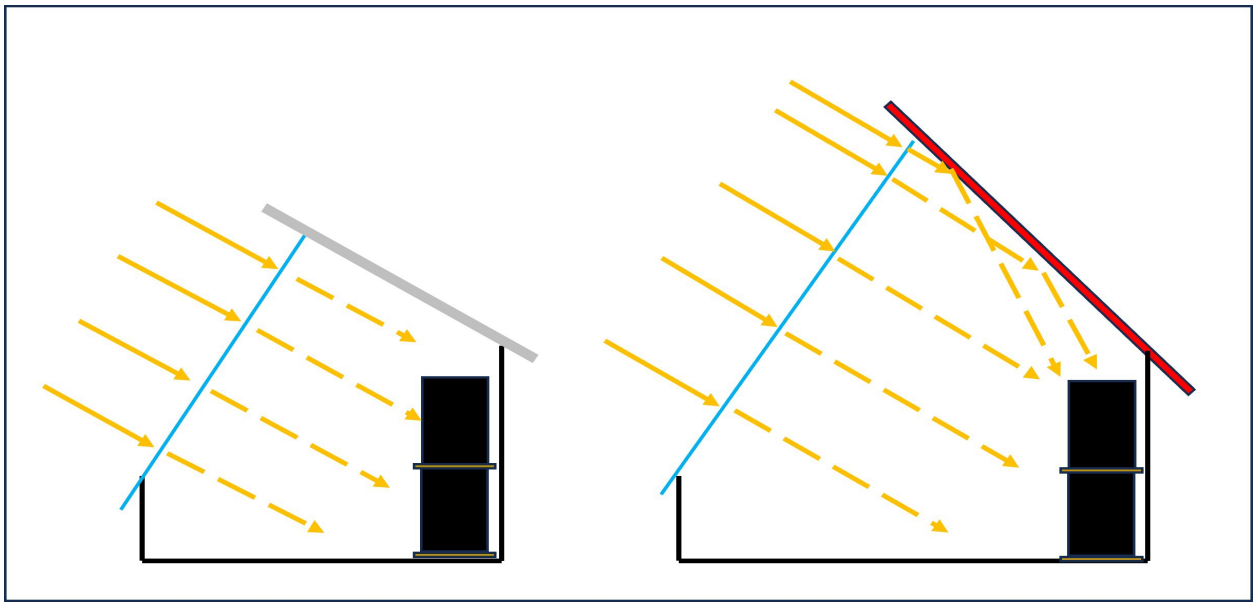


Figure XIII.2. With the sun in the winter at about 30^0 above the horizon, light streams in more or less parallel with the roof in the original design (left). Increasing the roof angle to 45^0 from horizontal gives a larger glazing area and greater widths of the PSG, enabling light to be reflected from the ceiling towards to the floor and thermal mass.

Angle of the south-facing glazing

The capture of solar energy is the primary factor driving the photosynthetic and thermal success of the SunCatcher. The most effective angle of the SunCatcher's glazing is approximately 60^0 up from horizontal at most latitudes above 24 degrees, as this angle maximizes available solar energy during the coldest period of the year.[1] Conversely, this angle reduces sunlight transmission into the structure during the summer months, preventing overheating.

At the 60^0-angle of the glazing, the amount of sunlight captured by the structure varies based on the north roof angle, which can be between 45 and 60 degrees up from horizontal. A larger roof angle increases the glazing area and the amount of available sunlight. In addition, a steeper roof reflects more light from the ceiling toward the thermal mass and the plants in the winter months. There are, however, three drawbacks to steeper roof angles: (1) A taller building is subject to higher wind loads; (2) The larger glazing area created by a steeper roof will loose more heat and will probably need a nighttime insulation curtain on cold winter nights; and, (3) The higher ceiling may create more air stratification in the greenhouse, requiring fans to mix and blow the warm air downward in the Winter period.

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[1]While we believe that for locations above 23.5^0 north or south latitude, 60^0 up from horizontal is optimum, we want to acknowledge the old formula for determining the best glazing angle for your specific location: *optimum glazing angle = latitude + 20-35^0 from horizontal*. This can lead to complicated and difficult angles for cutting and placing the rafters, adding extra work and time. We base our 60^0 recommendation on how sunlight itself acts rather than the greenhouse location as others do.

Reducing the glazing angle to be closer to horizontal reduces the amount of incoming sunlight in the Winter as most sunlight will be bouncing off the glazing. The more laid-back angle of the glazing also allows the greenhouse to cool off more (radiate heat out the roof as infrared radiation) on clear winter nights! During other times of the year (Spring through Fall), glazing at a smaller angle from horizontal will allow larger amounts of light (and thus heat) to enter the greenhouse when it is not needed, overheating of the structure (at the expense of less winter light and heat being available when it is needed) (bottom of Figure XIII.3 and photos below).

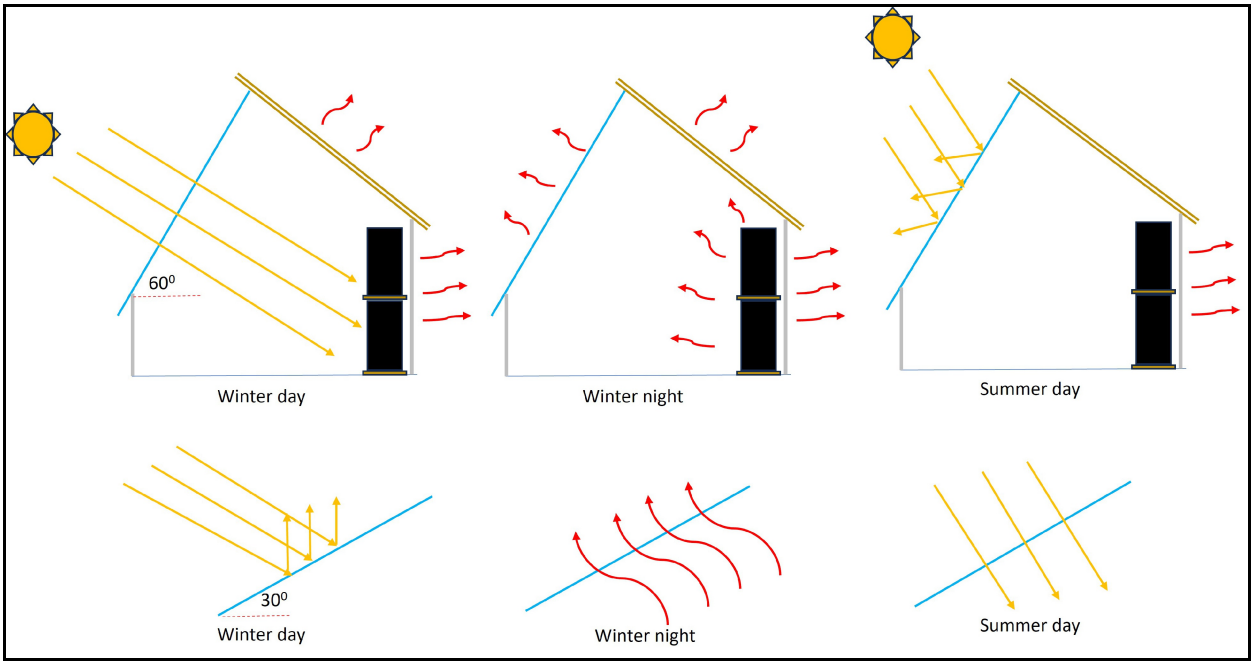


Figure XIII.3. Sunlight transmission and heat loss (red arrows) with different glazing angles during the winter and summer months. A more laid-back glazing angle (as in Chinese PSGs) reflects most sunlight during the winter months while losing more heat, while it will over-heat during the summer months.





Left: Passive solar greenhouse with laid-back roof, Sugar Grove, NC uses water-filled Sunlight tubes as thermal mass. Right: The Ceres "PSG" at the SD Farm, Fleetwood, NC with a 40^0 from horizontal roof and GHAT system - not exactly passive solar with about 2400 kWh/month electricity usage.



Left: Light reflected by the glazing (morning of July 11, 2024) will keep the SunCatcher's interior shady and cooler than ambient temperature and the sunny outside. Right: More sunlight is transmitted into the SunCatcher on October 30, 2024, which may overheat the structure at that time of the year (as well as in Spring) if no shade cloth is used.

PSG size: the length-width-height ratio

The length of your SunCatcher should be at least twice its width to ensure that all of the interior space gets direct sunlight for at least half the day. The longer the structure is compared to the width of the east and west walls, the more sunlight is available in the center of the PSG for photosynthesis and heat collection by the thermal mass (Figure XIII.4). For a SunCatcher with a larger footprint, we suggest using the same profile and making the structure longer with the use of exhaust fans in the upper windows in both the east and west walls. We do not recommend louvered fans, as they do not seal well and will cause unnecessary heat loss during the winter. On warm, sunny winter days, you may need to open the upper vents for ventilation, so sealing louvered vents with, for example, blue board will be extra work.

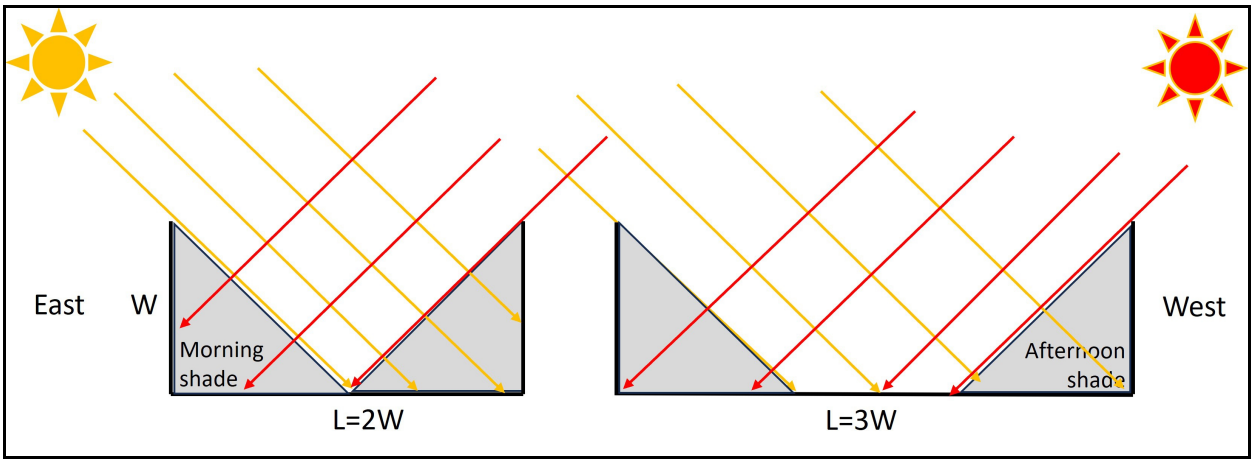
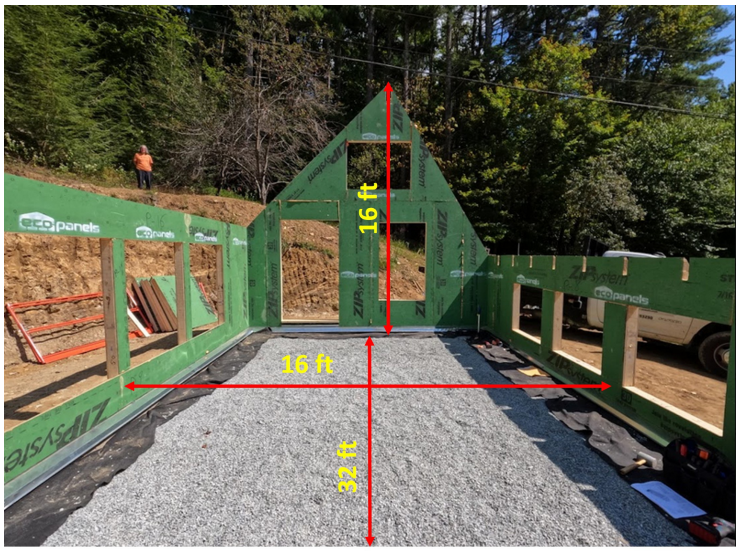


Figure XIII.4. At a length = 2x width, the entire SunCatcher get equal amounts of sunlight throughout the day. If length and width are equal, the North wall and plants along it) will always be shaded, while at lengths greater than twice the width, the center of the structure will receive more light.

Based on our research and experience, making the greenhouse wider is NOT recommended as there will be insufficient light for adequate plant growth along the north one-third of the interior. An alternative possibility is to build multiple SunCatchers (instead of one large one) for the square footage grow area you will need. It would be best to place them side-by-side rather then one in front of the other so that they will not shade the SunCatchers behind them (to the north) in wintertime.

The unique geometry means the SunCatcher's height will be roughly equal to its width. With a 45^0 angled north roof, a 12 ft wide SunCatcher will be about 12-14 ft high; a 16 ft wide SunCatcher will be about 16-18 ft high. The exact height is determined by the angle of the north roof and the height of the south and north walls. It is important to note that increasing the width of the greenhouse and not the height will result in too little light for plants to grow well on the north one-third of the greenhouse.



For SunCatchers longer than 32 ft, you may want to add some mechanical assistance to the upper vents, although we have not experimented with the following techniques:

- Place electric box fans behind or in each upper vent window, as shown in this picture of the New Zealand SunCatcher.
- Mounting 2 ft (60cm) diameter ducts about 1/4-1/3 the length of the greenhouse on the cross ties with a fan mounted on either end to blow the air from the center of the greenhouse toward the upper exhaust vents/windows. Note that solid ducts may block sunlight reaching the back (north) side of the greenhouse in the winter.
- A variation of this is two squirrel fans mounted on the center cross ties to which you would attach plastic sleeves (using greenhouse plastic) of the same diameter as the fans 1/4-1/3 the length of the greenhouse. When the fans are turned on, the sleeves inflate to blow the air toward the upper exhaust windows, but deflate and hang loosely over the crossties when not in use. The clear greenhouse plastic would cause minimal shading during the winter period.

Walls

The north wall can vary from 6-8 ft in height, which will allow for 55-gallon drums (about 2 ft in diameter and 3 ft tall) to be stacked on top of each other the length of the north wall. A 6' north wall would be just tall enough for two stacked drums, but insufficient as 2x4in.'s or ½ in. plywood should be placed under and between barrels for insulation purposes. If rafters are used to support the roof, you have to allow for those as well. An 8 ft north wall uses standard size materials more efficiently and also provides a growing space above the drums that is a warm

shaded area to germinate seeds and for plants that do not like direct sunlight. The higher north wall also makes the structure taller, which takes more material but allows a larger glazing area and more sunlight into the structure.

North wall vents are optional, but help with convective ventilation during the late Spring through early Fall warm season, preventing the greenhouse from overheating and getting too humid. A more constant supply of CO_2 also benefits the plants in the greenhouse.

The south-facing knee wall can vary from 3-4 ft in height, and should have operable windows which are a critical part of venting the greenhouse to regulate temperature, humidity and CO_2/O_2 levels during the winter period. A secondary benefit of south-facing knee-wall windows is some extra light in the winter from sunlight reflected by snow on the ground.

The East and West walls have access doors as well as two operable windows - one beside the door and one in the top center - the latter is key to make convective ventilation work without the use of fans. The east windows provide light for photosynthesis earlier in the day before the sun will shine more directly on the glazing, while the west windows do so in the late afternoon. However, the West windows may overheat the structure if allowed to do so (remember, the greenhouse has been warming up all day, and may not need an extra burst of heat in the late afternoon) – window shades can be used if necessary.

North roof



The solar aperture (south-facing glazing area) of the SunCatcher is designed to maximize the amount of natural photosynthetic light entering the greenhouse in the winter. The ceiling and interior walls have surfaces which reflect the incoming solar radiation back toward the plant growing areas and thermal mass. These two features increase the amount of natural light reaching the plants compared to the amount of light that same foot print outside of the structure would normally receive during the winter months. The large winter shadow on the north side of the Parkway PSG (photo) is caused by that light being "captured" and reflected inside the structure for additional sunlight within. With the interior reflection of light entering from many directions the design almost eliminates phototropism in plants.

Light intensity varies widely from one area to another due to atmospheric conditions and weather patterns. To increase the total amount of solar radiation entering a PSG, the aperture (i.e., the surface area of the glazing) can be enlarged to allow more sunlight in. As we discussed earlier in this chapter, increasing the angle of the roof increases the aperture as well as making the building

taller. The downside is that with more glazing there is also more heat loss.

In areas with, at times, extreme overcast conditions during the winter months (for example, Buffalo, NY), a SunCatcher with both the glazing and the north facing roof set at a 60° angle can increase the total solar collection area. And having the roof and glazing at those steep angles can be a good thing given the possible snow loads there!

The north roof should extend 10-12 inches above the glazing rather then meet the glazing as in a gable roof. The overhang serves two useful functions:

1. It provides ladder support to work on the glazing (during installation and periodic washing/cleaning, preventing scratches and possible cracks.



2. It provides an easy place to attach an exterior shade cloth without having the cloth laying on the surface and possibly scratching the glazing. During times (mostly Spring & Fall) when there is more sunlight entering the PSG than needed, the use of a light colored or silver shade cloth over the glazing can reflect some of the sunlight preventing overheating the PSG. This could be a manual or motor-driven system similar to the ones used for roll-up/drop-down side walls in high tunnels. An exterior awning could also be attached to that overhang (but don't deploy on very windy days!).